Reprinted from:
The Surgical Clinics of North America
August, 1966. Volume 46, Number 4.
Baylor University—Texas Medical Center Number
Published by W. B. Saunders Company

Resection and Graft Replacement of Aneurysms Involving the Transverse Arch of the Aorta

MICHAEL E. DE BAKEY, M.D.; ARTHUR C. BEALL, JR., M.D.

DENTON A. COOLEY, M.D.; E. STANLEY CRAWFORD. M.D.

GEORGE C. MORRIS, JR., M.D.; H. EDWARD GARRETT, M.D.

Aneurysms of the aortic arch, particularly those involving the transverse arch, have long been considered among the most serious forms of this disease. While the basic principles of excisional therapy for these aneurysms are similar to those located in other parts of the aorta, their application to this segment are associated with greater technical difficulties and more hazardous consequences. This is derived primarily from the fact that temporary arrest of aortic circulation is an essential requirement for excisional therapy except in the occasional case of sacciform aneurysm (Fig. 1). In this region of the aorta temporary arrest of circulation, even for relatively brief periods, produces two critically important and potentially hazardous effects. The first of these is caused by the sudden increase in vascular resistance upon the heart with left ventricular strain that may rapidly lead to acute heart failure. The second is concerned with possible ischemic damage to the tissues distal to the occlusion, particularly those of the central nervous system.

Accordingly, methods used to control these problems assume critical significance in the successful application of surgical treatment for aneurysms of the aortic arch. Depending upon the nature, extent, and location of the lesion, several methods may be employed for this purpose in accordance with the following classification:

From the Cora and Webb Mading Department of Surgery, Baylor University College of Medicine, Houston, Texas

Supported in part by the U.S. Public Health Service (HE-05435) and (HE-05387) and the Houston Heart Association.

PRINTED IN U.S.A.

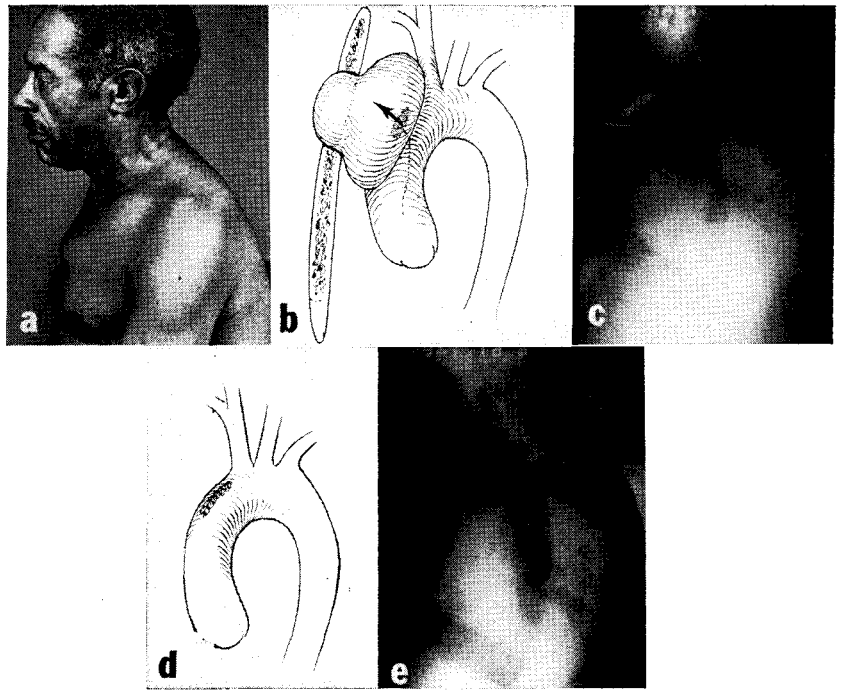

Figure 1. Sacciform aneurysm of luetic origin involving proximal transverse arch of aorta treated by excision and lateral aortorrhaphy in a 68 year old Negro: (*a*) photograph of patient demonstrating erosion of sternum by aneurysm, (*b*) drawing illustrating aneurysm arising just proximal to origin of innominate artery, (*c*) angiogram demonstrating sacciform aneurysm and dilatation of entire thoracic aorta, (*d*) drawing illustrating lateral aortorrhaphy, and (*e*) angiogram 2 years after operation demonstrating area of lateral aortorrhaphy and continued dilatation of entire thoracic aorta. Area of lateral aortorrhaphy found to be well healed at time of pneumonectomy for carcinoma of lung 5 years later.

1. Aneurysms involving the proximal or entire ascending aorta (these are considered in another report of this issue)
2. Aneurysms involving the transverse arch but not the proximal part of the ascending aorta
3. Aneurysms involving the entire ascending aorta and transverse arch.

OPERATIVE APPROACH

Temporary bypass of the transverse aortic arch requires maintenance of distal blood flow not only to lower portions of the body supplied by the descending thoracic aorta, but also to the upper part and particularly to the brain supplied through the brachiocephalic vessels. When the proximal portion of the ascending aorta is uninvolved by the aneurysm, bypass can be accomplished by the use of a temporary system of grafts providing circulation both to the brain through the innominate and common carotid

arteries and to the lower part of the body through the descending thoracic aorta. However, if the aneurysm extends to involve the proximal ascending aorta as well as the transverse aortic arch, techniques of temporary cardiopulmonary bypass with extracorporeal perfusion of the cerebral circulation are required.

Aneurysms limited to the transverse aortic arch usually are approached through a bilateral anterior third intercostal space incision with transverse division of the sternum. If additional exposure becomes necessary, this may be obtained by a superior extension of the incision and division of the sternum (Fig. 2, *a*). In some instances in which it may be necessary to attach the distal limb of the temporary bypass graft well down on the descending thoracic aorta owing to extensive involvement of its proximal segment by the aneurysm, it is often helpful to elevate the left side of the patient on a roll in order to extend the incision on this side more laterally. In such cases it has been found preferable to extend the incision from the right third intercostal space across the sternum into the left fourth intercostal space in order to provide better exposure of the lower descending thoracic aorta.

Attachment of the temporary bypass graft is begun by anastomosing the end of an 18- or 20-mm. tubular Dacron graft to the side of the descending thoracic aorta distal to the aneurysm using a partial occlusion vascular clamp (Fig. 2, *b*). Once this anastomosis is completed, a straight vascular clamp is placed across the graft flush with the suture line and the partial occlusion clamp is removed. The other end of the graft is then similarly attached to the ascending aorta proximal to the aneurysm (Fig. 2, *c*). A 16- or 19-mm. bifurcation Dacron graft is attached to the tubular graft in such a manner that its limbs will easily reach the brachiocephalic vessels without kinking (Fig. 2, *d*).

Next, the end of the right limb of the bifurcation graft is attached to the side of the innominate artery distal to the aneurysm, using a partial occlusion clamp (Fig. 2, *e*). Care must be exercised not to compromise blood flow through the innominate artery during this maneuver, and as soon as the anastomosis is completed a straight clamp is placed across the graft flush with the suture line and the partial occluding clamp is removed. Final attachment of the temporary bypass graft requires anastomosis of the end of the left limb of the bifurcation graft to the side of the left common carotid artery distal to the aneurysm. Owing to the small size of this vessel, use of a partial occlusion clamp is usually not feasible, and distal flow through the carotid artery during anastomosis is accomplished by use of a temporary internal shunt of polyethylene (Fig. 2, *f*).

Immediately prior to completing the left carotid anastomosis, the internal shunt is removed (Fig. 2, *g*), and upon completion of the anastomosis a straight vascular clamp is placed across the graft flush with the suture line. All necessary attachments of the temporary bypass graft now are in place, provided the right vertebral artery has been demonstrated adequately for perfusion of the basilar arterial system. Otherwise, the left vertebral

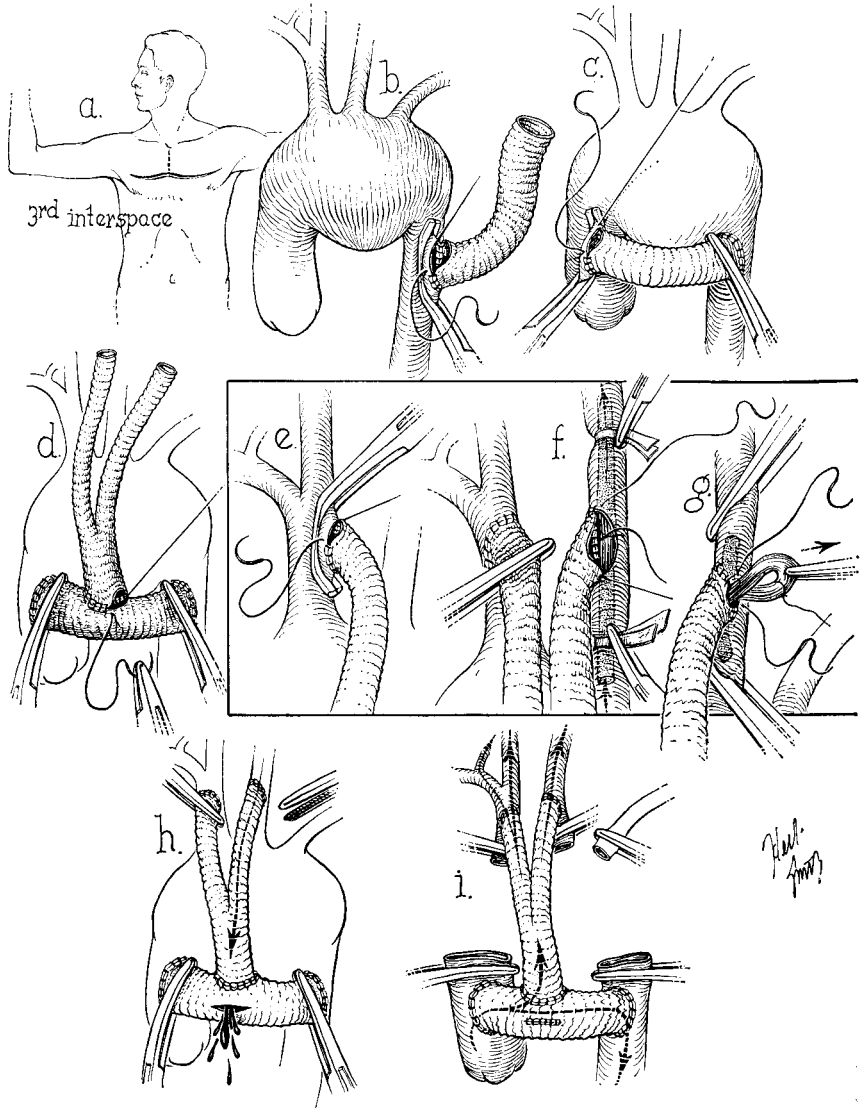

Figure 2. Technique for resection and graft replacement of aneurysm involving transverse arch of aorta using temporary bypass graft (see text).

(*Continued on facing page.*)

artery must be perfused by attachment of the left subclavian artery to the temporary bypass graft. Prior to establishing blood flow through the bypass, a small incision is made in the tubular graft and each vessel attached to the bypass is flushed individually, removing any thrombotic material that might have formed, and evacuating all air (Fig. 2, *h*). Finally, a partial occlusion clamp is used to close this incision, all other clamps are removed allowing onset of blood flow through the bypass, the incision in the excluded

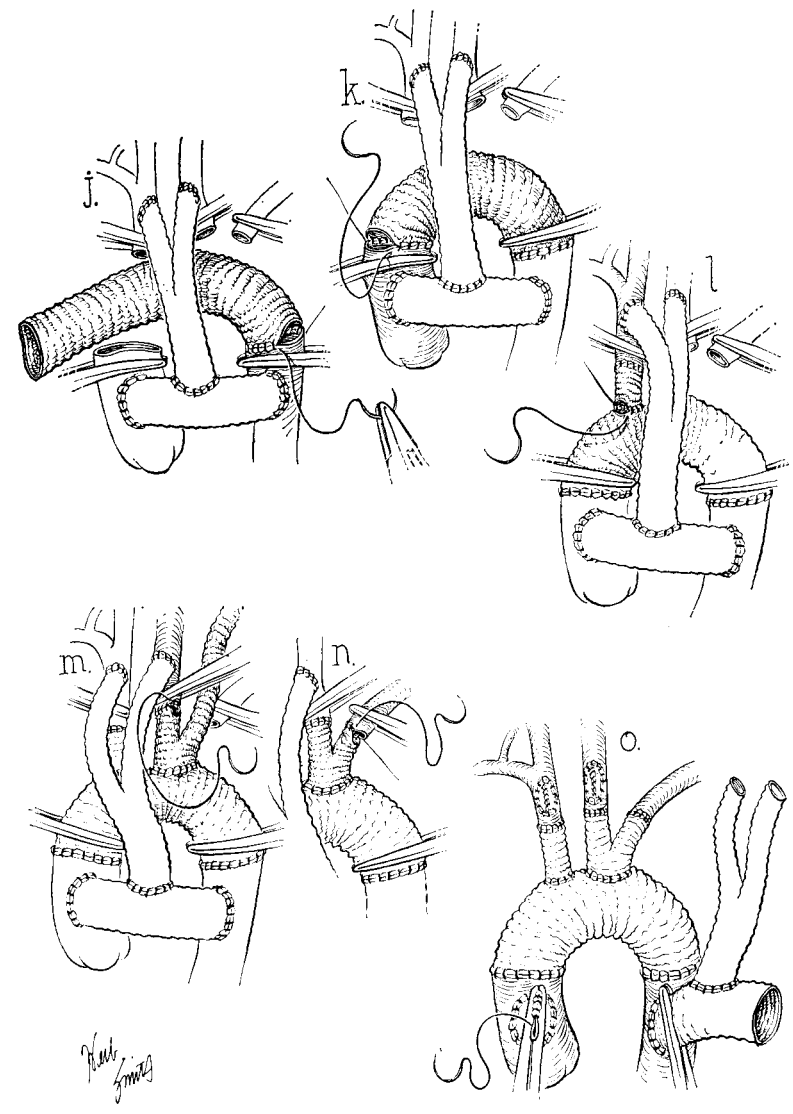

Figure 2 (*Continued*).

portion of the tubular graft is repaired, and the partial occluding clamp is removed.

With distal flow to the brain through both carotids and one vertebral artery and to the lower portion of the body through the descending thoracic aorta now established, the ascending aorta distal to the attachment of the temporary bypass graft but proximal to the aneurysm is occluded with a vascular clamp. The descending thoracic aorta, innominate artery, and left common carotid artery then are clamped distal to the aneurysm but proximal to the attachments of the temporary bypass graft, and the left

subclavian artery is clamped distal to the aneurysm. With blood flow through the aneurysm thus arrested, the aneurysm is excised (Fig. 2, *i*). During aneurysm excision care must be exercised not to injure or enter surrounding structures such as the pulmonary artery. For this reason it is often preferable not to attempt removal of the outer wall of the aneurysm which is intimately adherent to adjacent structures, limiting oneself to removal of the thrombus in the lumen and the necrotic intimal lining.

Graft replacement is begun by end-to-end anastomosis of an appropriate-sized tubular Dacron graft to the distal cut end of the descending thoracic aorta (Fig. 2, *j*). This graft is cut to length and its other end is anastomosed to the proximal open end of the ascending aorta (Fig. 2, *k*). Using tubular Dacron grafts of appropriate size (8 or 10 mm.), side arms then are anastomosed progressively by end-to-side anastomosis to the aortic arch graft and by end-to-end anastomosis to the distal cut ends of the innominate, left common carotid, and left subclavian arteries (Fig. 2, *l–n*). Although in certain instances a previously prepared graft with side arms may be applicable, it has been our experience that it is preferable to construct the graft as it is attached in order to obtain proper fitting of the graft without kinking. In some instances it is possible to use a bifurcation graft for attachment to two of the brachiocephalic vessels, thus eliminating one anastomosis (Fig. 2, *m–n*).

Once permanent graft replacement is complete except for finishing the final anastomosis, each attached vessel is flushed individually, removing any thrombotic material that may have formed and evacuating all air, following which the final anastomosis is complete and all clamps are removed. With blood flow now established through this permanent graft, the temporary bypass graft is removed. Usually, this is easiest and best accomplished by placing a vascular clamp across each limb of the temporary bypass graft flush with its anastomosis, cutting the limbs a few millimeters distal to the clamps, oversewing these cut ends, and finally removing the clamps (Fig. 2, *o*). Such a method of temporary bypass graft removal also prevents possible narrowing of the vessels by the suture line, serving much as a patch closure of each area of the temporary bypass graft attachment.

Residual outer wall of the aneurysm now is used to provide viable coverage of the graft for fibrous tissue ingrowth. Bilateral thoracostomy tube drainage is established and the wound is closed in layers. Antibiotics usually are employed for five to seven days. In the event a tracheostomy is required, it should be performed high and well above the area of superior mediastinal dissection.

Application of this procedure for aneurysms of the transverse aortic arch is dependent upon presence of sufficient length of normal aorta between the aortic valve annulus and the proximal extent of the aneurysm for attachment of a temporary bypass graft. Availability of such a segment for bypass graft attachment often cannot be determined with certainty until the chest is opened, therefore a pump oxygenator must be immediately

available should such a segment not be found. This now is possible by use of disposable plastic oxygenators* primed with 5 per cent dextrose in distilled water. Then, if the aneurysm is found to extend so far proximally as to prevent use of temporary bypass graft techniques, temporary cardiopulmonary bypass with extracorporeal perfusion of the cerebral circulation may be employed (Fig. 3).

Temporary cardiopulmonary bypass from the venae cavae to the femoral artery first is instituted, and extracorporeal perfusion of the cerebral circulation next is established by cannulation of the innominate and left common carotid arteries (Fig. 3, *c*). The aneurysm then is entered and myocardial viability is maintained by extracorporeal perfusion of the coronary arteries (Fig. 3, *c*). Once aortic continuity is re-established by anastomosis of a graft to the distal cut end of the descending thoracic aorta and to the proximal cut end of the ascending aorta at the aortic valve annulus, extra-

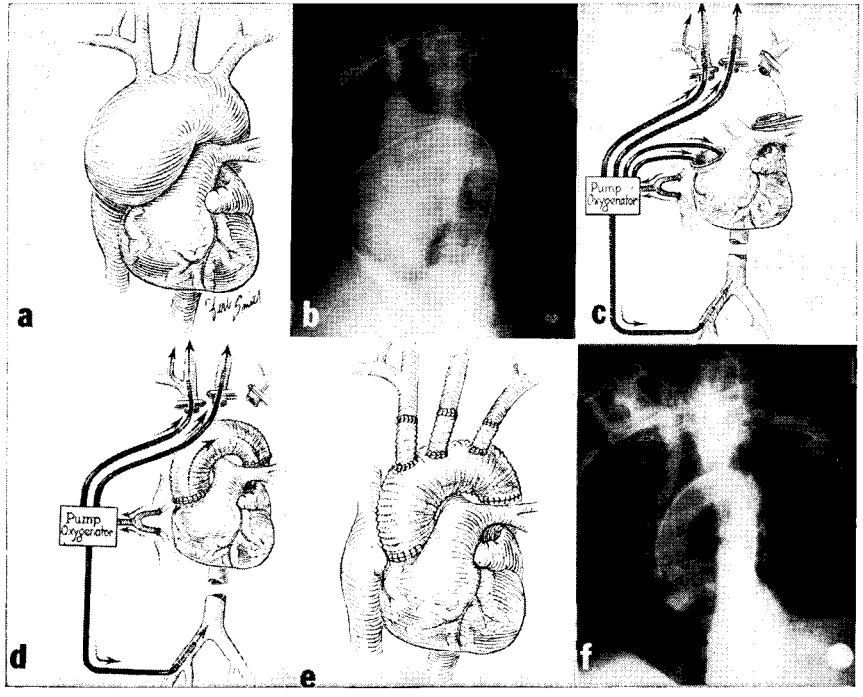

Figure 3. Fusiform aneurysm of arteriosclerotic origin involving entire ascending aorta and transverse aortic arch in a 57 year old while man: (*a*) drawing illustrating and (*b*) angiogram demonstrating location and extent of aneurysm, (*c*) drawing illustrating technique of temporary cardiopulmonary bypass with extracorporeal perfusion of cerebral and coronary circulations, (*d*) drawing illustrating re-establishment of aortic continuity with graft, allowing decannulation of coronary arteries, (*e*) drawing illustrating and (*f*) angiogram more than 1 year after operation demonstrating graft replacement of entire ascending and transverse arch of aorta. Patient has returned to full-time employment and remains asymptomatic 2 years later.

* Travenol Laboratories, Inc., Morton Grove, Illinois.

corporeal perfusion of the coronary arteries may be discontinued as myocardial circulation then is provided by a combination of cardiac action and arterial return from the pump oxygenator to the femoral artery (Fig. 3, *d*). Operation is completed by progressive attachment of side arms to the brachiocephalic vessels, anastomosing these to the aortic graft using a partial occluding clamp and progressively discontinuing extracorporeal perfusion of the cerebral circulation. Finally, temporary cardiopulmonary bypass is discontinued (Fig. 3, *e*), hemostasis is obtained, the graft is covered with viable tissue, and the wound is closed.

TECHNICAL CONSIDERATIONS

Although techniques of temporary bypass using either grafts or extracorporeal circulation are relatively standardized, techniques of permanent graft replacement vary with the individual case. Rarely, the bypass graft can be converted into a permanent graft, but such a maneuver usually is prevented by the size of the aneurysm and the resultant length of temporary bypass graft necessary to circumvent the area of aortic involvement while the aneurysm is still in place. Use of a bifurcation graft for permanent attachment to distal cut ends of two of the brachiocephalic vessels often may be employed to shorten the procedure somewhat (Figs. 2 and 4). In other instances the remaining length of one or more vessels is sufficient for direct attachment to the permanent aortic graft (Fig. 5). Occasionally, a common trunk to two vessels may be found and a single tubular graft serve for attachment of both of these vessels to the aortic graft (Fig. 6). Occasionally too, the aneurysm may not involve the superior surface of the aorta from which the brachiocephalic vessels originate and it may be possible to tailor a tubular graft into place in such a manner as to replace only the inferior surface of the transverse aortic arch (Fig. 7).

Some aneurysms involving the transverse arch of the aorta are sacciform in nature and, while it may be possible in those with a relatively narrow neck to close the defect by simple suture (Fig. 1), in others this method of repair may be associated with some hazards resulting from tension upon the suture line or encroachment upon the lumen. Under these circumstances, patch repair of the aortic defect remaining after aneurysmal excision may be employed (Fig. 8). Occasionally, aneurysms involving the ascending aorta and transverse arch may spare the distal portion of the arch and origin of the left subclavian artery, under which circumstances only the involved area is excised and replaced with a graft (Fig. 9). Regardless of the method of permanent graft replacement employed, however, the technique utilized must be adapted to both the individual patient and the specific lesion. As much information about the location and the extent of the lesion as possible should be obtained prior to operation, but only after the aneurysm is exposed can a final decision be made as to the technique of graft

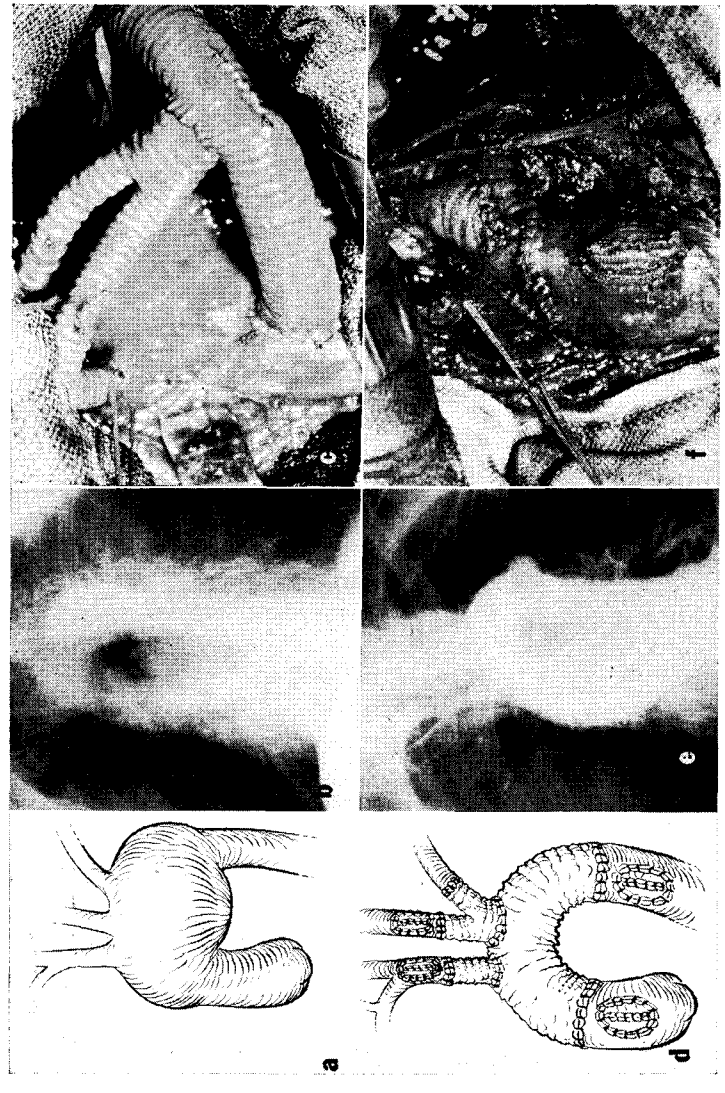

Figure 4. Photographs, angiograms, and drawings of arteriosclerotic fusiform aneurysm of aortic arch in a 58 year old white man showing use of bifurcation graft for permanent attachment to distal cut ends of left common carotid and left subclavian arteries: (*a*) drawing illustrating aneurysm involving transverse aortic arch, (*b*) angiogram before operation demonstrating aneurysm, (*c*) operative photograph demonstrating temporary bypass graft, (*d*) drawing illustrating graft replacement, (*e*) angiogram 1 year after operation demonstrating graft replacement, and (*f*) operative photograph demonstrating graft replacement. Patient remains well 5 years later.

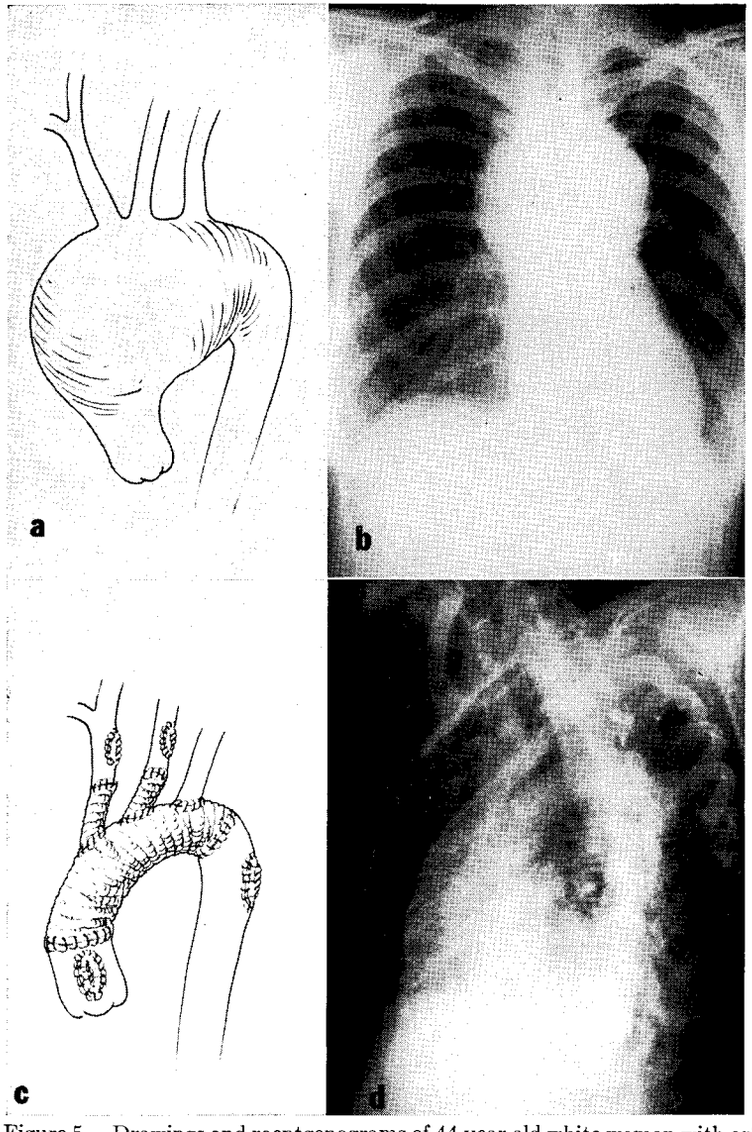

Figure 5. Drawings and roentgenograms of 44 year old white woman with arteriosclerotic fusiform aneurysm of aortic arch showing direct attachment of distal cut end of left subclavian artery to aortic graft: (*a*) drawing illustrating aneurysm, (*b*) roentgenogram of chest demonstrating aneurysm, (*c*) drawing illustrating graft replacement, and (*d*) angiogram 7 years after operation at which time patient remained asymptomatic.

replacement to be utilized or even the method of temporary bypass required. However, if one is prepared to resect the aneurysm and re-establish circulatory continuity by whatever means are applicable, then few, if any, aneurysmal lesions of the transverse aortic arch can be considered technically inoperable.

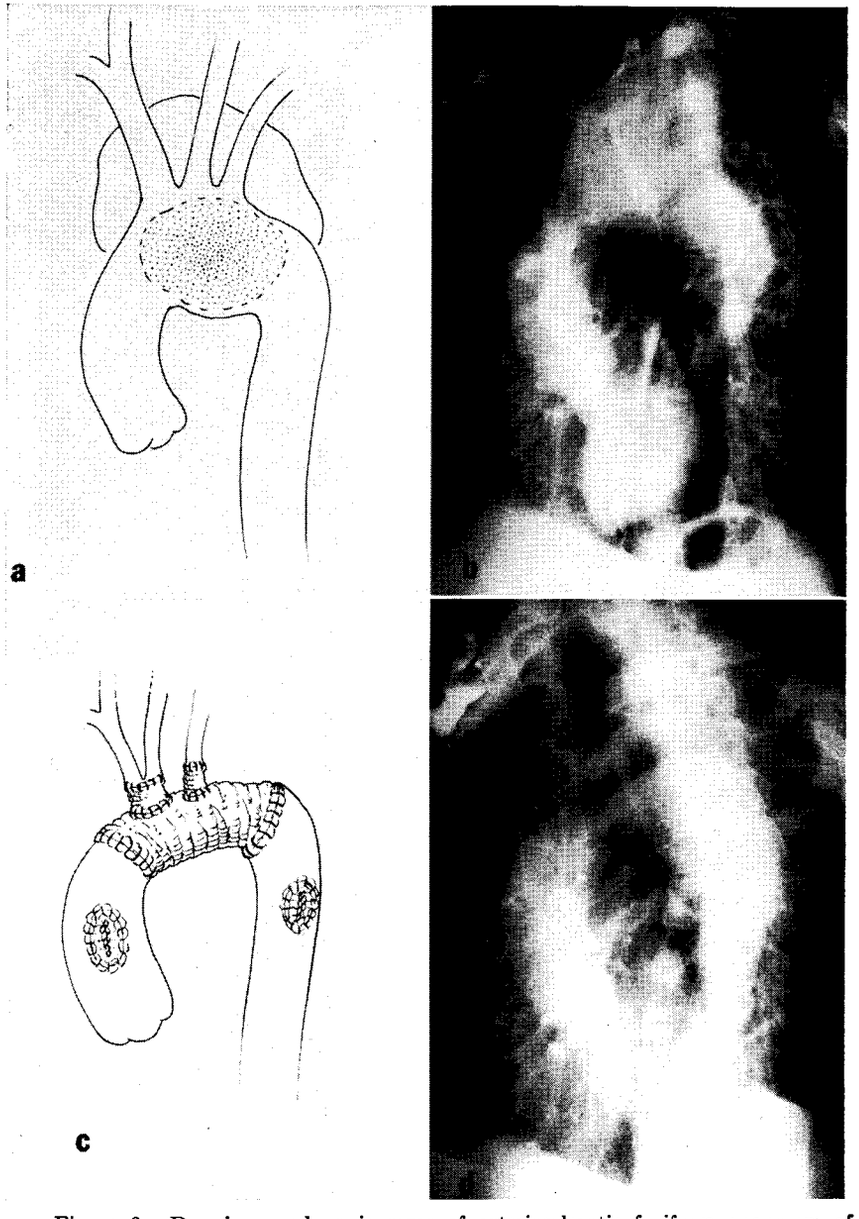

Figure 6. Drawings and angiograms of arteriosclerotic fusiform aneurysm of aortic arch in a 51 year old white man showing common trunk to innominate and left common carotid artery allowing attachment to aortic graft with single tubular graft: (*a*) drawing illustrating aneurysm, (*b*) angiogram demonstrating aneurysm, (*c*) drawing illustrating graft replacement, and (*d*) angiogram 6 years later demonstrating graft replacement. Patient remains asymptomatic 7 years after operation.

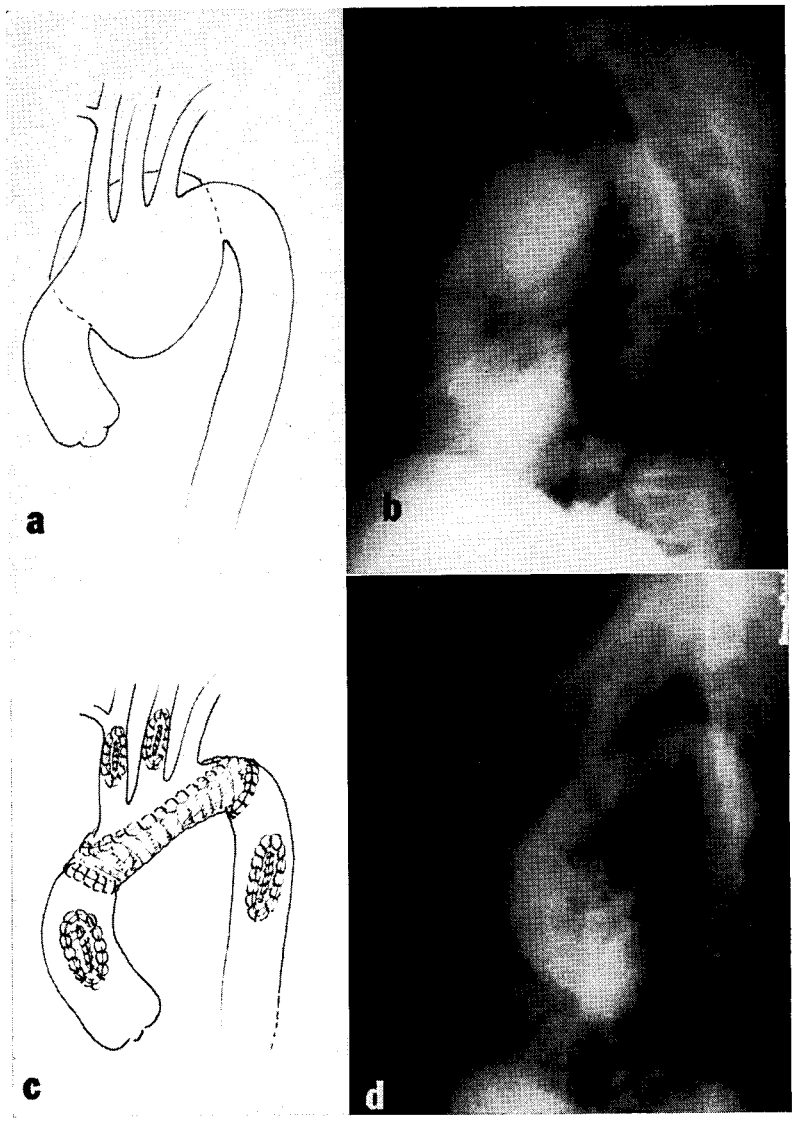

Figure 7. Drawings and angiograms of arteriosclerotic fusiform aneurysm of aortic arch in a 54 year old white man showing graft tailored in such manner to leave top of aortic arch with origins of brachiocephalic vessels intact: (*a*) drawing illustrating aneurysm, (*b*) angiogram demonstrating aneurysm, (*c*) drawing illustrating graft replacement, and (*d*) angiogram 3 years after operation demonstrating graft replacement. Patient remains asymptomatic 5 years after operation.

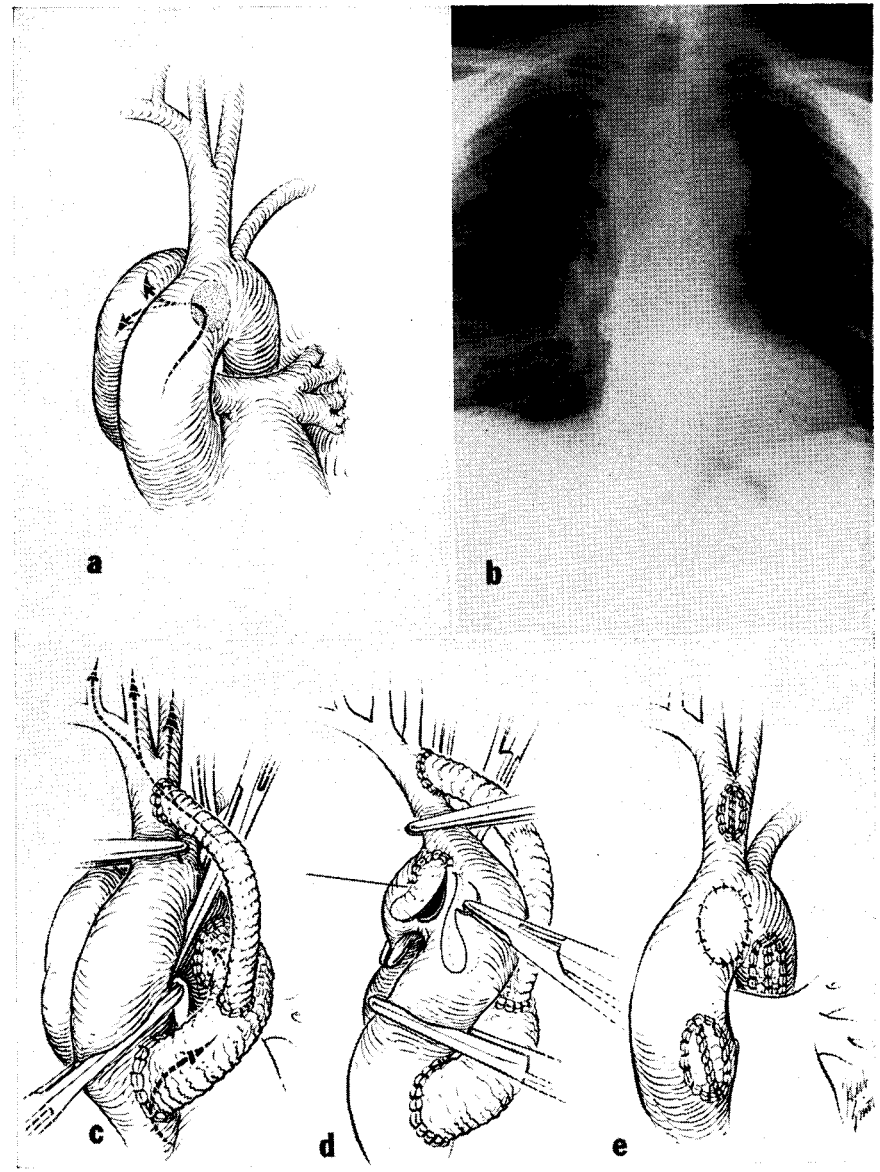

Figure 8. Drawings and roentgenograms of luetic sacciform aneurysm of aortic arch in a 60 year old white man showing patch graft repair: (*a*) drawing illustrating aneurysm, (*b*) roentgenogram of chest demonstrating aneurysm in superior mediastinum, (*c*) drawing illustrating technique of temporary bypass graft, (*d*) drawing illustrating patch repair, and (*e*) drawing illustrating completed operation. Note innominate and left common carotid arteries arising from common trunk. Patient remains asymptomatic 7 years later.

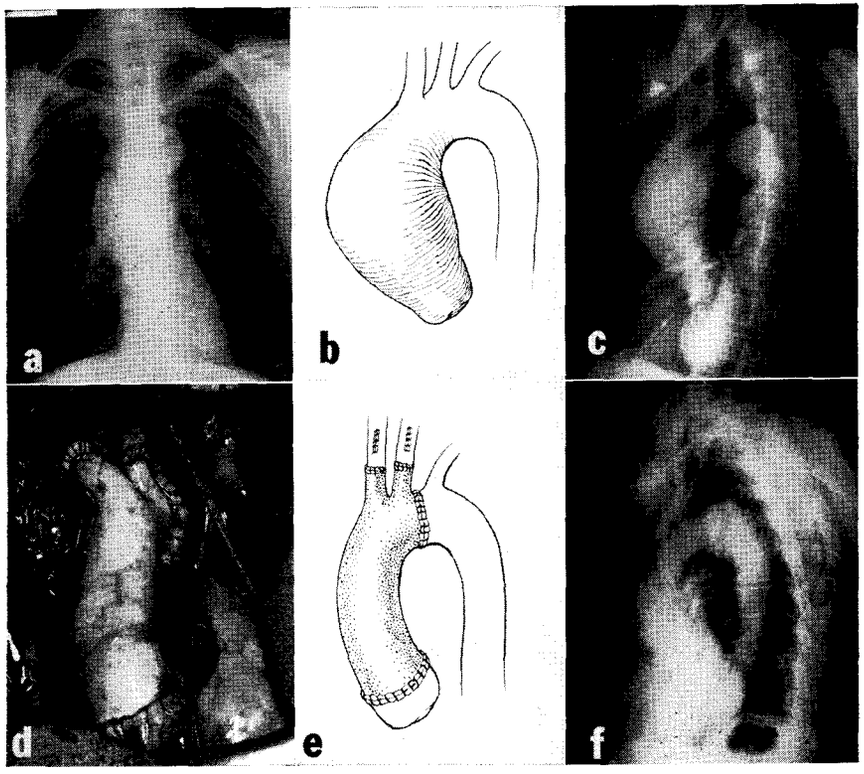

Figure 9. Drawings, roentgenograms, and photograph of luetic fusiform aneurysm involving entire ascending and major portion of transverse aortic arch in a 56 year old white man requiring temporary cardiopulmonary bypass with extracorporeal perfusion of cerebral and coronary circulations during resection and graft replacement: (*a*) postero-anterior roentgenogram of chest demonstrating calcification in wall of aneurysm, (*b*) drawing illustrating and (*c*) angiogram demonstrating location and extent of aneurysm, (*d*) operative photograph demonstrating homograft replacement of entire ascending and portion of transverse aortic arch including origins of innominate and left common carotid arteries, (*e*) drawing illustrating and (*f*) angiogram 7 years later demonstrating successful operation. Patient remains asymptomatic more than 9 years after operation.

DISCUSSION

Aneurysms involving the transverse arch of the aorta present a significant threat to the well-being and even the life of the patient. These lesions frequently produce symptomatic compression of the trachea and/or esophagus similar to that associated with congenital vascular rings. With large aneurysms in this area, recurrent laryngeal nerve involvement is not unusual. And, contrary to the situation which exists once an abdominal aortic aneurysm ruptures into the retroperitoneal space, little or no temporary tamponading effect is produced by superior mediastinal tissues. This factor, as well as the necessity for construction of a temporary bypass graft prior to arrest of circulation through the aneurysm, makes operation exceedingly difficult and hazardous once rupture has occurred.

Therefore, elective resection and graft replacement of aneurysms of the aortic arch usually is indicated, in spite of the necessary complexity of the surgical approach. Although advanced age increases somewhat the risk of operation, age per se should not be a limiting factor in selection of patients for surgical therapy. Of far more significance in regard to risk is the presence or absence of significant associated disease, particularly ischemic heart disease.

Experience with more than 50 patients with aneurysms involving the transverse arch of the aorta has clearly demonstrated significance of associated heart disease in that more than half of all deaths have been of cardiac origin. Overall salvage rate has been more than 60 per cent and with increasing experience in the management of these lesions now approximates 80 per cent. Follow-up studies extending more than nine years have demonstrated that operations, such as those described, allow complete rehabilitation and long-term survival of patients with aneurysms involving the transverse arch of the aorta. Such results appear most gratifying when compared to the extremely grave prognosis that can be expected when such patients do not receive definitive surgical therapy.

SUMMARY

Surgical therapy of aneurysms involving the transverse arch of the aorta presents certain technical problems, related primarily to the necessity of maintaining both cerebral circulation and circulation to the lower portion of the body during the procedure of aneurysmal resection and graft replacement. Methods of temporary bypass employed for these objectives depend upon whether or not the aneurysm extends to involve the proximal ascending aorta. If this area remains uninvolved in the aneurysmal process, a system of temporary bypass grafts may be utilized. However, aneurysms involving the entire ascending and transverse aortic arch require temporary cardiopulmonary bypass with a pump oxygenator and extracorporeal perfusion of the cerebral and coronary circulations. Once such a temporary bypass graft is functioning, the aneurysm is excluded from the circulation and excised, followed by graft reconstruction using one of a variety of techniques depending upon the exact location and extent of the aneurysm and upon certain anatomical variations. Risk of operation relates primarily to associated cardiac disease, and overall results of surgical therapy are most gratifying in altering an otherwise grave prognosis of patients with aneurysms involving the transverse arch of the aorta.